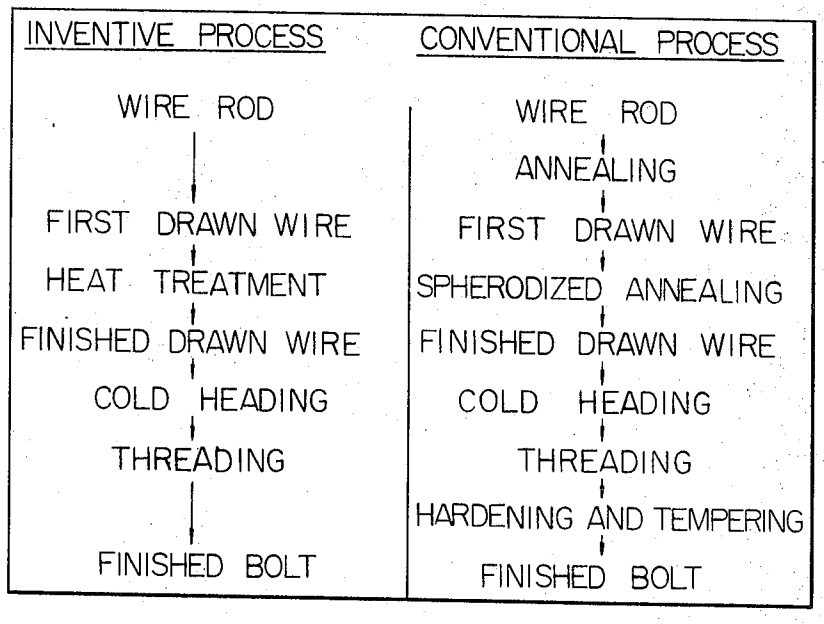
Oct. 6, 1970 MITSUO TOMIOKA ETAL 3,532,560

COLD-WORKING PROCESS

Filed Oct. 20, 1967 3 Sheets-Sheet 1

Fig. 1



MITSUO TOMIOKA
KOICHI URAKAWA *INVENTORS*

BY

Otto John Munn
Attorney.

Oct. 6, 1970 MITSUO TOMIOKA ETAL 3,532,560
COLD-WORKING PROCESS
Filed Oct. 20, 1967 3 Sheets-Sheet 2

Fig. 2

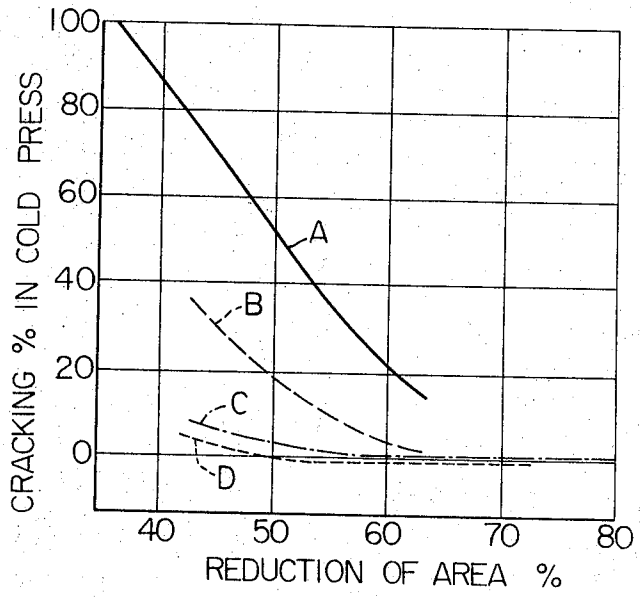
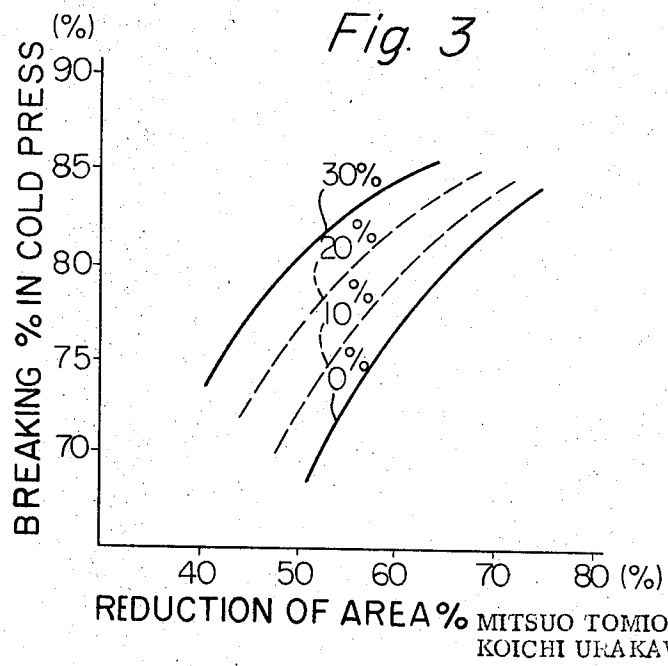


Fig. 3



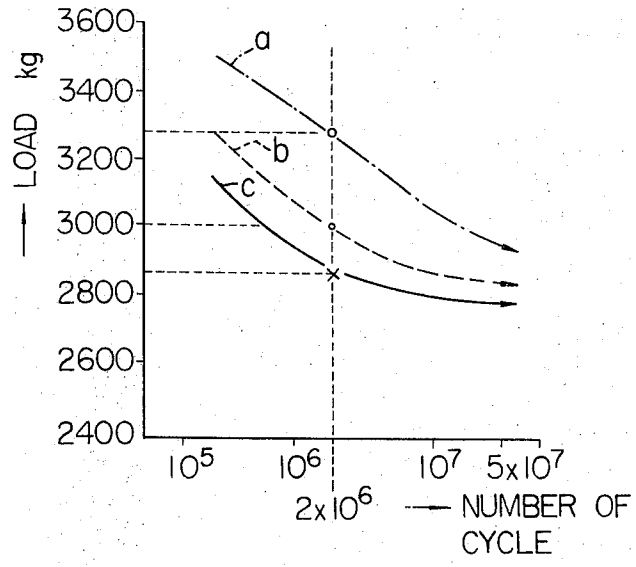
MITSUO TOMIOKA INVENTORS
KOICHI URAKAWA
BY Otto John Munz
Attorney

Oct. 6, 1970 MITSUO TOMIOKA ETAL 3,532,560

COLD-WORKING PROCESS

Filed Oct. 20, 1967 3 Sheets-Sheet 3

Fig. 4



MITSUO TOMIOKA
KOICHI URAKAWA *INVENTORS*

BY Otto John Munz
Attorney

United States Patent Office

3,532,560
Patented Oct. 6, 1970

3,532,560

COLD-WORKING PROCESS

Mitsuo Tomioka, Nishinomiya-shi, and Koichi Urakawa, Kobe-shi, Japan, assignors to Kobe Steel Works, Ltd.

Continuation-in-part of application Ser. No. 358,317, Apr. 8, 1964. This application Oct. 20, 1967, Ser. No. 677,507

Claims priority, application Japan, Apr. 18, 1963, 38/20,395

Int. Cl. C21d 9/52, 1/18

U.S. Cl. 148—12.4 3 Claims

ABSTRACT OF THE DISCLOSURE

A process of heat treating and cold working steel or related alloys into finished products, such as bolts and machine parts, having superior properties. The process is characterized by the sequential steps of heat treating at a temperature above the A3 transition temperature of the steel or alloy, quenching; tempering at a temperature between 300° to 700° C., cooling to ambient temperature and then cold forging or cold working the treated metal into the desired product.

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of application Ser. No. 358,317 filed Apr. 8, 1964 now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to a process for producing cold-shaped or forged products having excellent mechanical properties and high fatigue limits from a length of a continuous elongated shaped steel article such as steel wire, rods, bars and the like (hereafter it should be recognized that although the discussion is directed to steel wire, other continuous elongate shapes could be used) which has been previously tempered under particular conditions.

DISCUSSION OF THE PRIOR ART

Bolts, studs, pins and other machine parts which are required to have high tensile strength (in excess of 70 kg./mm.^{2}) are usually produced by a process in which carbon steel containing carbon in excess of 0.3% by weight or steel alloy containing an alloy element selected from the group consisting of chromium, nickel and molybdenum is processed by cold-forging, hot-forging or cutting the steel material and then subjecting the thus obtained intermediate product to a quality adjusting step such as hardening or tempering so as to impart predetermined mechanical properties to the final product. Alternatively, according to another conventional process, a length of previously tempered steel material is cut to the desired size and shape to provide a final product or machine part having predetermined mechanical properties.

The above enumerated machine parts may also be produced by a conventional cold-shaping process which usually comprises selecting a length of coiled steel wire (this material will be merely referred to as "steel wire" hereinafter) as the starting material to be processed and then cold shaping the steel wire in a cold shaping machine in a continuous operation. However, if the steel wire material contains carbon in excess of 0.3% by weight or has an excessively high degree of hardness, the steel wire may break or fissure during the cold shaping operation or the thus obtained product may have insufficient tensile strength. Thus, in an effort to eliminate these disadvantages the cold-shaping processes of the prior art frequently use the so-called spherically annealed steel wire as the

starting material to be cold-shaped. The annealed steel wire is then cold shaped and subjected to a further tempering treatment so as to obtain a machine part or product having a high tensile strength and predetermined mechanical properties. Therefore, in order for conventional steel wire to be suitably employed as the starting material to be cold-shaped into a machine part, the steel wire must be first subjected to an annealing or spherical annealing treatment in order to reduce the hardness of such a steel wire to a level suitable for the cold shaping operation. However, since such annealing treatments are carried out at a high temperature ranging from 700° to 900° C. for a rather long period of time covering 5 to 10 hours, the steel wire is liable to form a deoxidized layer or layers during the annealing treatment. Further, since the tempering treatment is the last stage in a series of stages involved in the cold shaping of a machine part, the tempering treatment has to be carried out in a non-oxidizing atmosphere furnace or salt bath soaking pit; otherwise it is quite difficult to obtain a product having satisfactory quality.

In addition to the above disadvantages, there is the additional disadvantage that different lots of the products will inevitably have different qualities and dimensions from each other because they are subjected to the heat treatment in lots, and, therefore, the products may fail to show their expected performance and may fail after they are incorporated into a machine.

Another prior art process is the so-called patenting process which has been widely used for the purpose of continuous heat-treating of steel wire. However, the patenting process is applicable to only the production of high tensile strength steel wires such as hard steel wires, piano wires and spring steel wires and this process has been developed to cold-stretch high carbon steel wires having carbon contents in excess of 0.6% by weight. To put it more concretely, the patenting process comprises the steps of heating steel wire to a temperature about its A3 transition point and quenching the steel wire in a lead bath soaking pit heated to 400° to 600° C. so as to temper the steel material. Since the patenting treatment primarily has been developed as a pre-treatment step in the cold-stretching operation of hard steel wires having high carbon contents such as piano wires for example, the patenting treatment is not applicable as a pre-treatment process in the cold-forging of steel wires having carbon contents less than 0.6% by weight for producing machine parts. That is, it is possible to obtain fine grain structures for high carbon steel wires having carbon content above 0.6% by weight, but in case of carbon steel wires having a carbon content of less than 0.6% by weight, the wires treated by the patenting process will have uneven grain structures due to insufficient quenching. And when steel alloys containing manganese, nickel and chrome in a range of 1 to 3% respectively are treated by the patenting process, such treated wires will have uneven grain structures wherein bath decomposed and undecomposed portions co-exist, and thus, by the patenting treatment, uniform fine grain sorbite structures for steel wires cannot be obtained.

In short, by the conventional patenting process, it is impossible to obtain uniform fine grain sorbite structures for steel wires having carbon contents or 0.2 to 0.6% by weight to such degree that the steel wires may be cold-forged into final products or machine parts without the necessity for further heat treatment after production thereof.

The novel process of our invention makes it possible so obtain uniform fine grain sorbite structures for steel wires and this process can be clearly distinguished from the conventional patenting treatment process.

In addition to the patenting treatment process, many other processes have been so far proposed for heat treating steel wires continuously, but unfortunately, no technical ideas exist which advance such prior arts to the production of machine parts such as bolts and pins through cold-forging. The present invention is important in that the same continuous steel wire heat treatment technology is utilized for the production of cold-forged or shaped products or machine parts by the use of tempered steel wires.

SUMMARY OF THE INVENTION

In this sense, it can be said that the present invention does not represent a merely mechanical combination of heat treatment and sold-shaping steps for steel wires, but rather is a novel process which has been developed on the basis of findings of the workabilities of materials to be cold-forged or shaped.

After a thorough study of workabilities of materials to be cold-shaped, we have found that the efficiency of the cold-shaping operation has almost nothing to do with the degree of hardness of the particular steel wire to be cold-shaped, but rather greatly depends upon the mechanical properties of the particular steel wire employed, especially the drawability and microstructure of the steel wire. Based on the above discovery we have provided a novel cold-forging process which includes a tempering step and which eliminates the above-mentioned disadvantages inherent in the conventional cold-shaping processes. According to the present invention, there is provided a improved cold-forging process for producing cold-shaped products which comprises the steps of rapidly heating a running length of carbon steel wire or steel alloy wire to a temperature above the A3 transition point of the steel material while continuously reeling out of a roll of coiled wire; quenching said heated steel wire by means of cooling agent such as water or oil so as to harden the wire; rapidly heating said quenched steel wire to a temperature 300° to 700° C.; cooling said heated wire to room temperature by means of cooling agent such as water or compressed air so as to temper the wire whereby a length of tempered wire having a uniform fine grain sorbite structure is obtained; and cold-forging said tempered steel wire into products having prescribed shape and dimention by a cold-forging machine. The steel wires suitably employed as the starting material in carrying out the novel process by the present invention include carbon steel wire containing carbon in an amount of 0.2 to 0.6% by weight and alloy steel wire containing one or more of silicon, manganese, nickel, chromium, molybdenum, vanadium and boron in an amount less than 3% by weight respectively in addition to carbon in the above prescribed content range. That the amount of carbon be within the aforementioned range is particularly critical; this criticality will be explained in greater detail below in the preferred embodiment.

DESCRIPTION OF THE DRAWINGS

In respect to the drawings:

FIG. 1 shows a block flow sheet for a conventional cold-shaping process and for the process of our invention;

FIG. 2 graphically shows the relationship between micro-structures and percentage of break or crack occurrence for various types of steel wires;

FIG. 3 graphically shows the relationship between critical cold compressive amounts and percent reductions in area on various cold-forged steel wires; and

FIG. 4 is a graph of load-number cycle curves for bolts produced by our process and bolts prepared by conventional processes—as discussed in Example I.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Considering the drawings in greater detail, FIG. 1 shows a flow sheet comparison between a conventional prior art process and the novel process of our invention. As is readily apparent on the face of this figure, our process, as well as producing a superior product, results in the elimination of several costly and time-consuming steps required in the prior art process. Further advantages of our process and the products produced thereby are enumerated as follows:

(1) Since, according to our process, the steel wire used as the starting material is continuously subjected to the tempering treatment in its wire form as it was produced, the thus tempered steel material has uniform mechanical properties and microstructure throughout its length, and, accordingly, disparity in quality of products processed from such a tempered material is quite rare.

(2) Since products or cold-forged parts processed from the steel wire tempered by our process do not require any further heat treatment after production thereof, accuracy in shape and dimension of such products can be maintained and, especially, the same is true in the case of small diameter and long products.

(3) Because the effect of residual compression stress on the surfaces of cold-forged products, which are characteristic of such products, the obtained products have various excellent mechanical properties, especially an excellent resistance to repetitive fatigue.

(4) Since our process eliminates the time-consuming annealing or spherically annealing treatment which is necessary in the conventional processes for preparing steel wires, there will be no possibility for the formation of deoxidized layers as in the conventional spherical annealing treatment; that is, this opportunity for decrease in surface strength and decrease in resistance to fatigue can be prevented.

(5) By preparing cold-forged products from tempered steel wire in accordance with our process, as compared with the conventional processes, the actual production process can be greatly simplified, resulting in a reduction in production costs as well as improvement in quality.

FIGS. 2 and 3 are particularly useful in considering the workability of materials to be cold-forged, especially since as to the workabilities of materials to be cold-forged, there has been no established definition up to date. However, through our strenuous studies of the workabilities of various materials we have concluded that the cold workabilities of steel materials are essentially determined depending upon the chemical compositions and heat treatment processes, and expressed in the terms of mechanical properties and microstructures of such materials. Up to now, it was considered that the workability of materials having high hardness and high tensile strength was poor. However, after our studies and experiments, we are convinced that even some steel materials having high tensile strengths can be properly cold-forged without difficulty provided that they satisfy certain specific requirements. This point will be explained in detail referring to FIGS. 2 and 3 of the accompanying drawings.

FIG. 2 graphically shows relations between microstructures of various types of steel wires produced under different heat treatment conditions, such as S35C (AISI 1035), S45C (AISI 1045), SCr2 (AISI 5130), SCrR (AISI 5140), SCM3 (AISI 4135), SCr21 (AISI 5130) and the subsequent parenthetical terms indicating the standard U.S. nomenclature for the same steel wire; reductions of area of these wires determined through tension tests (horizontal), and percentage of break or crack occurrence during cold-forging with 80% of cold-compression ratio (vertical). In this figure, Curve A designates an annealed coarse grain structure steel wire, Curve B designates an annealed fine grain structure steel wire, Curve C designates a spherodized fine grain structure steel wire, and Curve D designates a tempered fine grain structure steel wire.

From the graph of this figure, it is clear that as the grain structures change from A to D the frequency of cold-forging breaking or cracking becomes less. In order to completely eliminate cold-forging breaks, the reduction in area of the steel wire must be above 70% in A wire and above 65% in B wire, respectively, whereas C and D wires show no cold-forging breaks even when the reduction in area is 50%. Thus, it is noted that the cold-workabilities of steel wires are greatly influenced by the mechanical properties and microstructures of the steel materials.

FIG. 3 shows graphically the relations between critical cold compressive amounts (the point at which a break takes place in steel wires) in cold compression tests and reductions of area percent in tension tests performed on various cold-forged steel wires which were cold-stretched under different drawing ratios. From the graph of FIG. 3, it is clear that even the drawing ratio of cold-forged steel wires amounts to such great degrees as 10 to 30%. Further, if the chemical compositions of steel materials and heat treatment conditions for such materials are so selected that the reductions of area in such materials may be great, the breaking point of such materials can be raised, that is, the cold workability of such materials can be improved.

The novel invention utilizes these excellent cold workabilities of tempered steel wires as shown in the graphs of FIGS. 2 and 3. Especially, since D steel wire has a fine grain sorbite microstructure, it is noted that this D wire has a high tensile strength and excellent workability. Therefore, it is mandatory that in order to industrially utilize such properties of these steel wires in producing cold-forged products from such steel wires, the chemical compositions of such steel wires and the treatment conditions for such materials should be properly combined depending upon the properties, strength and shape called for in the cold-forged products prepared from such materials. This novel combination of chemical compositions and heat treatment conditions can be achieved only by the present invention.

A specific and preferred embodiment of our invention will now be described. In the first step of our process, a plain carbon steel containing about 0.2 to 0.6% by weight carbon or an alloy steel also containing this percent of carbon and one or more of an alloying component such as silicon, manganese, nickel, chromium, molybdenum, vanadium, and boron, and preferably containing not more than 3% by weight of any given alloying metal, is selected.

The reason for which the amount of carbon to be contained in carbon steel wire as the starting material is specified as the range 0.2 to 0.6% by weight is that if the carbon content of the steel material is less than 0.2% by weight, the carbon content during the tempering treatment is insufficient to impart the prescribed mechanical strength, which will be called for by the desired product or machine part; and, if the carbon content of the steel wire is in excess of 0.6% by weight, a cold-forged product prepared from such steel material will not possess sufficient tensile strength to meet requirements for the desired cold-forged product. Where alloy steel is employed as the starting material to be cold-forged, the reason that that content for each of the alloying elements is specified as less than 3% by weight is that if one or more of these elements in the prescribed amount are properly incorporated into the base steel material, a product having excellent mechanical properties can be easily obtained through the tempering treatment. Although it is possible to use these alloying elements in excess of the prescribed amount, there may be no notable improvements in mechanical properties of the product over those of a product prepared from alloy steel wire containing the allowing elements in the prescribed amounts respectively, and, accordingly, the use of these alloying elements which are exepnsive in excess of 3% respectively is uneconomical. The incorporation of from 0.0007 to 0.003% by weight of boron into the steel will improve the heat treatment capability of the alloy steel wire and, accordingly, economy of the other alloying element or elements which are greater in amount than that of the boron additive.

Steel wire or alloy steel having the above-mentioned chemical compositions may be used as the starting material for our process in the form of unstretched wire as it is produced or these steel materials may be stretched prior to being subjected to our tempering treatment. When such stretcihng is used the amount of stretching is usually such as to effect a 13% reduction in cross-sectional area. In any case, through the tempering treatment of such steel materials, a tempered intermediate product having mechanical properties and uniform fine grain sorbite structure suitable for continuous cold-forging will be obtained.

In the next step of our process, the selected plain carbon steel wire or alloy steel wire having the required composition is rapidly heated to a temperature above the A3 transition point of the steel material of the steel wire.

This heating may be effected by continuously passing the steel rod, preferably at a rate of 2 to 6 m. per minute, through a suitable conventional high temperature heating means, such as for example a high frequency heating furnace, flame heating furnace, electric resistance heating furnace, electric furnace, heavy oil furnace, salt bath soaking pit or lead bath soaking pit, so that the steel wire may be maintained at a temperature range of 850 to 950° C. for 1 to 3 minutes. The purpose of the rapid heating of the steel wire is to obtain a uniform austenite structure of the steel wire. Also, heating of the steel wire to a temperature below 850° C. is insufficient to obtain a uniform austenite structure of the steel wire, and, accordingly, the insufficiently heated steel wire is difficult to harden uniformly. Alternatively, if the steel wire is heated to a temperature above 950° C., the steel wire will be overheated, resulting in deoxidation layer and/or rough surface formation which leads to a poor surface quality or coarsely hardened structure. Therefore, the rapid heating of the steel wire within the temperature range of 850 to 950° C. for a time space of 1 to 3 minutes is critical in order that the steel wire may be properly treated in the heat treatment step of the present process.

After having been rapidly heated to the temperature range of 850 to 950° C., the heated steel wire is passed to a quenching device, which is preferably directly connected to the preceding heating surface, where the heated steel wire is quenched by means of any suitable cooling agent, such as water or oil, until the innermost portion of the interior structure of the steel wire is cooled to a temperature below about 200° C. This provides the steel wire with a uniformly hardened structure throughout its mass. The type of cooling agent may be suitably selected depending upon the chemical compositon and diameter of the steel wire to be processed. When the diameter of the steel wire is smaller than 11 mm., oil is employed as the quenching or hardening agent whereas steel wire having a diameter greater than 11 mm. is quenched or hardened by means of water. In the quenching or hardening of the steel wire, it is necessary that the steel material be quenched until the interior structure of the steel material will also have a uniformly quenched structure as well as the exterior thereof. However, when the quenching is effected at an extremely rapid rate, breaks may occur in the steel wire. Therefore, it is preferable that the steel wire be quenched until the innermost portion of the interior structure of the steel material is cooled to 200° C., and thereafter the steel material is gradually cooled.

In order to determine whether the steel wire has been quenched to uniformly hardened structure or not, a microscopic test on the structure of the thus treated steel wire is carried out or a tension test on the tensile strengh of the thus treated steel wire is carried out. In the process of the present invention, after the steel wire having the

above-mentioned chemical composition has been subjected to the quenching or hardening treatment in the manner described above, it has been found that the treated steel wire has a tensile strength above 140 kg./mm.^{2}. So long as the tensile strength is not below the above value, uniform quenching or hardening is always attained.

The steel wire, now having a uniformly hardened structure, is then passed through a second heating furnace which is preferably connected to the above-mentioned quenching device and is maintained at 300° to 700° C. where the steel wire is evenly heated for a period of 2 to 10 minutes. The heated steel wire is then passed to a second cooling device which is preferably connected to the second heating surface where the steel material is cooled or tempered to room temperature by means of water or compressed air. The reason for specifying a heating temperature for tempering in the range mentioned above is that such a temperature range is necessary to impart mechanical properties suitable for cold-forging the specific type of steel wires to be processed by the process of the present invention, and especially for obtaining a desired area reduction value for the steel wires in a tension test and a fine grain sorbite micro-structure suitable for cold-forging the steel wires.

If the heating temperature for tempering is below 300° C., decomposition of the martensite structure of the steel wire in the hardened state into the fine grain sorbite structure thereof is insufficient and, although the tempered steel wire will have a high strength, its tenacity will be too low, and the steel wire will be unfit for cold-forging. Conversely, if the tempering heating temperature is in excess of 700° C., the decomposition of the martensite structure of the steel wire into the sorbite structure is too rapid, resulting in a coarse grain sorbite structure or a pearlite structure which reduces the tensile strength of the steel wire to a value below 70 kg./mm.^{2}. Therefore, a tempering heating temperature in excess of 700° C. is objectionable where it is desired to produce a tempered steel suitable for producing a cold-forged product having a tensile strength above 70 kg./mm. Accordingly, the heating temperature for tempering is an important factor and the heating or tempering temperature should be suitably selected within the specified temperature range of 300° to 700° C. depending upon the tesile strength desired in the final product, the diameter of the steel wire employed as the starting material, and the processing rate of the steel wire material. The cooling of the steel wire material from the tempering temperature to room temperature need not be rapid.

By the above heat treatment or tempering treatment, an intermediate steel product having a uniform fine grain sorbite structure and a tensile strength of 70–120 kg./mm.^{2} can be easily produced in a short space of time. The intermediate or tempered wire product is then subjected to a surface treatment such as pickling, lime and phosphoric acid film formation in the conventional manner so as to obtain a so-called tempered steel wire which may then be suitably cold-forged by conventional cold-forging machine into desired final products or machine parts.

In some cases, prior to the cold-forging operation, the tempered steel wire is stretched by an amount less than 20% reduction in area (usually about 13%) so as to adjust its diameter and tensile strength. The thus obtained tempered steel wire of uniform fine grain sorbite structure is then continuously cold-forged through a cold-forging or shaping machine so as to produce machine parts having a tensile strength of 70 to 120 kg./mm.^{2}, a high hardness and a high tenacity. Since the steps in the process of the present invention are carried out in succession, production efficiency is quite high; further, the shaped or forged products do not require any heat treatment after production, and products of precise dimensions can be easily obtained.

Our invention is further illustrated by the following examples but is not limited thereto.

Example I

This example illustrates our inventive process using a steel wire as the starting material having the following chemical composition:

	Percent
C	0.30
Mn	1.60
Si	0.30
P	0.030
S	0.30

A length of coiled steel wire having the above chemical composition (11 mm. in diameter and 350 kgs. in weight per roll) was first cold stretched to a diameter of 10.2 mm. and then passed through a Muffle type heavy oil furnace at a rate of 5 m./min. so as to heat the steel wire to a temperature below about 900° C. The thus heated wire was then quenched in an oil bath so as to reduce the temperature of the wire to a temperature below 200° C. The quenched wire was then tempered by being passed through a lead bath maintained at 600° C. at the same rate as that at which the wire was passing through the heavy oil furnace. After the lead bath tempering treatment the diameter of the wire was reduced to 9.45 mm. by cold finish stretching to obtain a length of tempered steel wire which was suitable for producing bolts of 3/8" diameter by cold forging.

The thus treated steel had a uniform fine grain sorbite microstructure and the following mechanical properties:

Yielding point—82 kg./mm.^{2}
Tensile strength—87 kg./mm.^{2}
Elongation—20%
Reduction of area—66%.

Next, this tempered steel wire was cold-shaped or forged by a cold shaping machine so as to form hexagon headed bolts of 3/8" diameter. The shaping machine produced six hexagon headed bolts per minute. The obtained bolts were further subjected to a screw-thread forming step while they were turned round to produce complete 3/8" x 50 mm. hexagon headed bolts.

The bolts were tested in accordance with the JIS bolt test procedure to determine their mechanical properties and the determined mechanical properties were compared with those of comparable bolts produced by the conventional processes. The JIS bolt test procedure is the same as the SAE Standard for "Mechanical and Quality Requirements for Threaded Fasteners—SAE J429C."

The results of the comparison are given below:

	Bolts produced by the novel process	Bolts produced by the conventional process (S45C) [i.e. AISI 1041]	Bolts produced by the conventional process (SCr2) [i.e. AISI 5130]
Yielding point (kg./mm.^{2})	86	82	85
Tensile strength (kg./mm.^{2})	90	87	90
Elongation (percent)	20	16	18
Reduction of area (percent)	65	57	63
30° wedge test	Good	Good	Good

The "30° wedge test" refers to a tension test which was performed by placing a 30° angle wedge between the bottom surface of the head of the bolt and the supporting surface of a supporting seat. Further, in accordance with the standard DIN procedure (i.e., DIN 267—Bolt Screws, Nuts and Similar Threaded and Formed Parts Technical Condition of Delivery), bolt head impact tests were performed on the above three types of bolts and good results were obtained on all of these bolts.

In addition, bolts produced by our process in the above Example I were compared with bolts made of S45C (AISI 1045) and SCr2 (AISI 5130), by the conventional process, by using Baldwin-type universal fatigue testing machine. Data was then obtained from which load-number

of cycle curves were prepared. The load was selected in the range of 2400–3600 kg., the cycle being in the range of $10^5 \sim 5 \times 10^7$. Curves *a*, *b*, and *c* were obtained as shown in FIG. 4. Curve *a* shows the results obtained from the bolts produced in accordance with the present invention, curve *b* being the results of conventional bolts made of AISI 1045, while curve *c* shows the results of conventional bolts made of AISI 5130. The load at the cycle of 2×10^6 is shown in the following table. The ratio of the load with respect to the yield strength in the static tension test of the bolts is also shown in the table.

TABLE

	Load, kg.	Ratio
(*a*) Bolts of the present invention	3,290	Y.P.×72%.
(*b*) Bolts of AISI 1045	2,860	Y.P.×67%.
(*c*) Bolts of AISI 5130	3,000	Y.P.×68%.

As is evident from the table, the bolt produced in accordance with the present invention is superior in fatigue strength than the conventional bolts. (These conventional bolts are produced by processes in which a length of steel wire is stretched, spherically annealed, again stretched, cold shaped hardened and finally tempered.) The bolts produced by our process also had especially excellent fatigue resistance which is especially desirable in respect to residual compressive stress encountered by the surfaces of the cold-forged products. The products produced by the present invention are characterized by these effects.

EXAMPLE II

This example illustrates our invention using a steel wire as the starting material having the following chemical composition:

	Percent
C	0.28
Mn	0.70
Si	0.25
Cr	0.80
P	0.30
S	0.030

A length of coiled steel wire having the above chemical composition (11 mm. in diameter and 360 kg. in weight per roll), from a roll of such a wire was first cold-stretched to a diameter of 8.5 mm. and then passed through a lead bath soaking pit maintained at 880° C., which used light oil as its fuel, at a rate of 2 m./min. so as to heat the steel wire to 880° C. in three minutes. The wire was then cooled to 200° C. by being passed through an oil bath whereby the steel wire was hardened to have a uniformly hardened structure. The tensile strength of the hardened steel wire was above 150 kg./mm.^{2}. The hardened steel wire was then passed through a tempering lead bath soaking pit maintained at 630° C., at the same rate as that at which the steel wire was passed through the first lead bath soaking pit. The steel wire maintained in this bath at a temperature of the steel wire at 630° C. for five minutes. The steel wire was then cooled to room temperature by means of compressed air. The above-mentioned series of treatments were consecutively performed throughout the entire length of the steel wire and the resulting steel wire had a uniform fine grain sorbite structure and a tensile strength of 85 kg./mm.^{2}. The thus treated steel wire was subjected to pickling and phosphate film forming treatment and then cold-stretched to reduce its diameter to 7.93 mm. so as to obtain a length of tempered steel wire to be suitably employed to produce JIS 8 mm. diameter bolts. The tempered steel wire had a uniform fine grain sorbite structure and the following mechanical properties:

Yield point—87 kg./mm.^{2}
Tensile strength—91 kg./mm.^{2}
Elongation—20%
Area reduction—67%.

The tempered steel was cold forged into ⅜" diameter hexagon headed bolts by a ⅜" bolt former (a three stage-transfer header) and then screw threads were provided on the stems of the bolts while the bolts were being turned about the longitudinal axes thereof so as to produce complete JIS 8 mm. diameter (M X 35 mm.) hexagon headed bolts.

The formation of cold-forged bolts from a length of tempered steel wire requires considerable mechanical working and specifically the steps of shearing, rolling, heading, trimming, and thread-cutting of the tempered steel wire. The tempered wire of Example II was subjected to these steps during the formation of the bolts and found to have, in spite of its high tensile strength, the same degree of cold-workability as that of the conventional annealed steel wire. Further, there were no breaks or cracks, flaws, etc., formed during the cold-forging operation.

The shear strength of bolts produced by the novel process was determined through tension tests with wedges disposed at different angles such as 10°, 20° and 30°, and the results of the tests are given below:

Wedge angle (degrees)	Tensile strength (kg./mm.^{2})	Location of breaks or cracks
10	101	Bolt stem.
20	99	Do.
30	100	Do.

As is seen from the above results of the tests, all breaks or cracks occurred in the stems of the bolts under consideration, but no breaks or cracks occurred in the heads of the bolts.

As a further comparison test, bolts processed from a length of tempered steel wire produced according to our process and bolts produced by the conventional processes were tested by a Baldwin type fatigue testing machine for their resistance to fatigue for comparison purposes and the results of the tests are given below:

	Bolts from tempered steel wire	Bolts by the conventional process
Static test:		
Yielding point (kg./mm.^{2})	81.5	86.5
Tensile strength (kg./mm.^{2})	91.0	95.5
Yield strength ratio	90.0	91.0
Fatigue test:		
Zero-tension endurance limit (kg.)	800.0	550.0
Endurance limit, ultimate strength ratio	140.0	100.0

Although there is no appreciable difference between the bolts by the novel process and those by the conventional process in regard to fatigue resistance in static tests, it should be noted that in regard to fatigue resistance to repetitive stress the bolts from the tempered steel wire have exceedingly high resistance as compared with that of the bolts by the conventional process. For claim purposes sorbite defines the formation of martensite upon quenching from the austenizing temperature and thereafter tempering at a temperature between 300° C. to 700° C.

It will be understood that modifications and changes may be made by those skilled in the art without departing from the scope and spirit of the present invention. Accordingly, the invention is not to be limited to the precise examples described hereinabove, but it is intended to cover also all changes, modifications and combinations of the embodiments described and/or claimed.

We claim:

1. A process for producing a cold-forged product which comprises the steps of:

providing a length of metal wire from a continuously unwinding coil, said metal selected from the group consisting of carbon steel containing about 0.2 to 0.6% and an alloy steel containing about 0.2 to 0.6% carbon, up to 3% manganese, up to 3% silicon and 0.0007 to 0.003% boron and at least one element

selected from the group consisting of up to 3% chromium, up to 3% nickel and up to 3% molybdenum;

rapidly heating the wire to a temperature above the A3 transition point of said metal and within the range of 850° to 950° C. while the wire is running at a predetermined rate;

maintaining the metal within this temperature range for 1 to 3 miuutes to sufficiently austenitize the same;

quenching the heated wire by means of a cooling agent until the innermost portion of the interior of the wire is cooled to a temperature of less than 200° C. thereby imparting a uniformly hardened martensite structure to the wire;

rapidly reheating the cooled wire to a temperature of 300° to 700° C. for about 2 to 10 minutes;

cooling the heated wire to about room temperature by means of a cooling agent so as to obtain a length of tempered wire having a uniform fine grain sorbite structure;

cold stretching the cold wire by an amount less than about 20% reduction in area; and

cold-forging the stretched wire into products having prescribed shape and dimension by a cold-forging machine.

2. The process of claim 1 wherein said cooling agent of the quenching step is selected from the group consisting of water and oil.

3. The process of claim 1 wherein the wire is cooled to effect tempering by being contacted with said second-mentioned cooling agent selected from the group consisting of water and air.

References Cited

UNITED STATES PATENTS

1,924,099	8/1933	Bain et al.	148—143
2,119,698	6/1938	Bayless	148—12.4
2,121,415	6/1938	Vom Braucke	148—12.4
2,341,264	2/1944	Coxe	148—12.4
2,441,628	5/1948	Griffiths et al.	148—143
2,527,731	10/1950	Ilacqua et al.	148—12.4
3,053,703	9/1962	Breyer	148—12
3,235,413	2/1966	Grange et al.	148—12.4

OTHER REFERENCES

Pomp, A., The Manufacture and Properties of Steel Wire, 1954, pp. 252–261.

L. DEWAYNE RUTLEDGE, Primary Examiner

G. K. WHITE, Assistant Examiner

U.S. Cl. X.R.

148—12, 143